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WETLANDS OF VICTORIA III. WETLANDS AND WATERBIRDS BETWEEN PORT PHILLIP BAY AND MOUNT EMU CREEK

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Abstract: Wetlands in the Western District were categorized by water regime and salinity, and subcategories were based on vegetation. Waterbird distribution and numbers were recorded during ground inspection and by counts at 135 sites in March, July and October 1980.

In all 1437 wetlands totalling 72 500 ha were located. They were of 6 categories, 23 subcategories and in sewage and salt evaporation systems. Permanent saline wetland (37 200 ha) and permanent open freshwater (16 100 ha) were the most extensive categories and permanent open freshwater (397) and freshwater meadows (371) the most numerous. Since European settlement 34% of the original area of freshwater wetland has been lost; most reduced have been shallow and deep freshwater marshes, with 79% and 66% lost respectively. Little saline wetland has been lost. Three hundred and seventy four impoundments (3580 ha), 4 salt evaporation systems (2180 ha) and 11 sewage oxidation systems (1680 ha) have been created since settlement.

Eighty six of the 110 waterbird species recorded were seen during the study period. On most wetland subcategories 5 to 10 species comprised more than 90% of the waterbirds using that subcategory. Many of these most abundant species occurred on most wetland subcategories. Wetlands with shallow permanent water support the highest densities of non-breeding birds (8 to 24 birds/ha) and average the most species (4 to 7) per visit. Assessment was made of the most important species in the various categories and whether they were breeding there or not. Some comments are offered on duck distribution based on duck band returns. Factors influencing the distribution of birds are discussed and the lack of freshwater meadows and shallow freshwater marshes in reserves for conservation is highlighted.

Earlier reports in this series (Corrick & Norman 1980, Corrick 1981) document the number, area and types of wetlands lost as well as the extent and waterbird use of remaining wetlands in south-eastern Victoria; in this report I present similar information for wetlands in western Victoria.

Study Area

The boundaries of the study area (Fig. 1) are Mount Emu Creek in the west, the main divide of the western highlands in the north, the eastern watershed of the Werribee River in the east and the coastline of Port Phillip Bay and Bass Strait in the south. It is approximately 19 000 km² or 8% of the area of the state.

The population of the area is approximately 350 000 (1978 estimate from Cowie 1980). Of these 45% live in Geelong and nearby settlements on the Bellarine Peninsula, 21% live in Ballarat, 15% in Bacchus Marsh and outer suburban centres of Melton and Werribee and the remainder in the few large country towns (Colac 10 500 and Camperdown 3600), numerous smaller towns and on rural properties. During summer the population of all coastal towns is increased sharply by holiday makers.

Physical Divisions

The study area may be divided into western highlands, volcanic plains, coastal plains and Otway Ranges (Hills 1964, Cowie 1980).

The western highlands occupy the northern quarter of the area. Elevation in this division is about 400 m and relief generally low near Ballarat where areas of basalt have filled river valleys; both the ancient interfluves and eruption points extend above this general level. To the south of Ballarat the Yarrowee and Moorabool Rivers are well embedded and about Bacchus Marsh relief is more pronounced where the Werribee River and its tributaries have formed steep gorges. The Otway Ranges, which occupy the southern tenth of the area, have been created by upwarping and faulting during the Tertiary to form a broad dome which grades gradually northward to the surrounding plain but dips sharply to the coast along the southern side. Although dissection is mature the topography is rounded due to land slip. The drainage patterns mirror the basic structure with the Gellibrand and Barwon Rivers draining the northern flanks and many small streams draining the southern slopes directly to the sea. On the northern edge of the Otway Ranges the coastal plains form a narrow strip between the ranges and the volcanic plain. They extend eastward to include the Bellarine Peninsula and westward to Peterborough and Warrnambool on the coast and are a partially dissected sedimentary surface which is flat or undulating with a veneer of Quaternary dune limestones and sands in places.

The final physical division, the basalt plains, covers the remaining half of the study area. The plains have a slight southward slope and prominent eruption

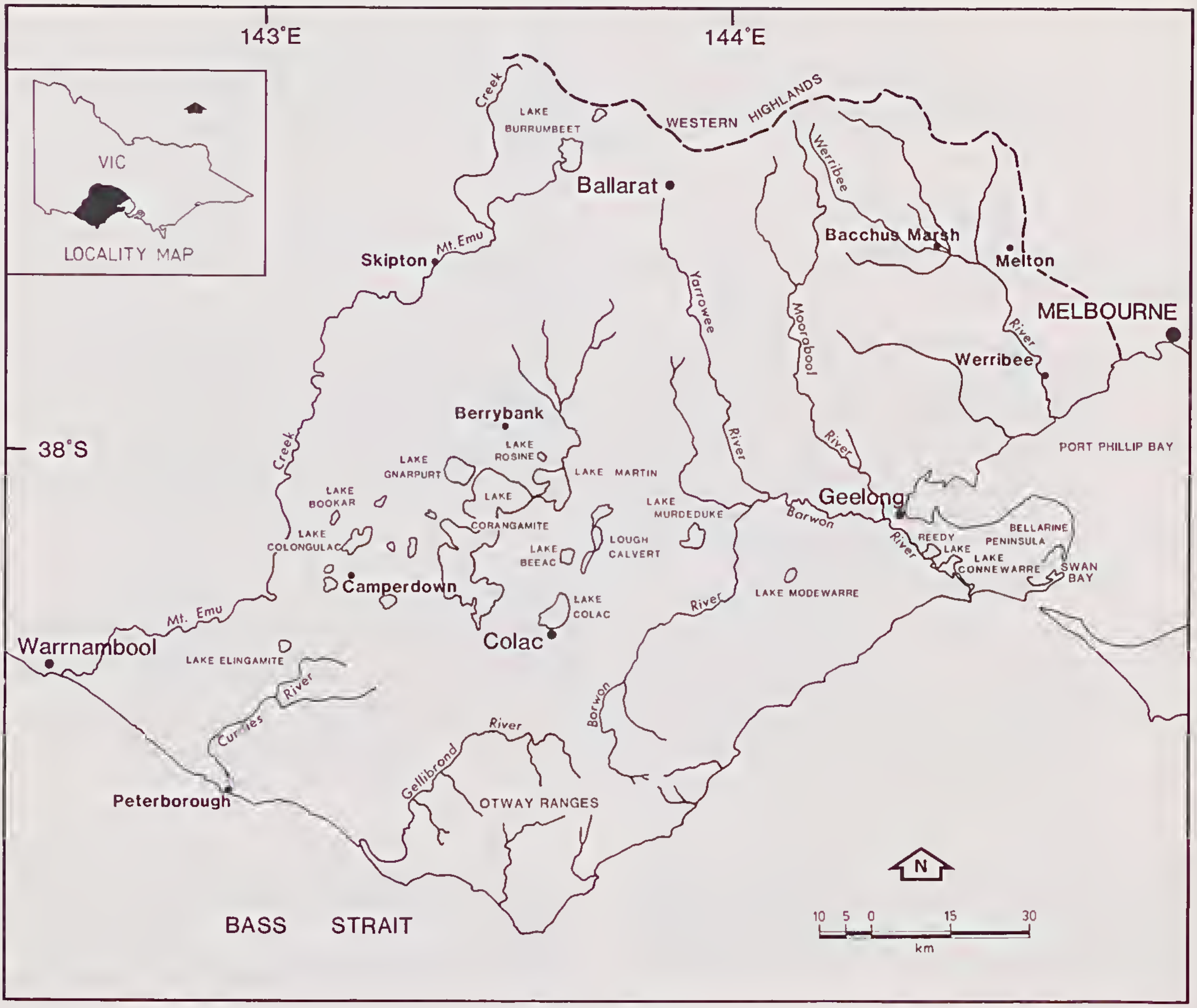

Fig. 1—The study area.

cent flows south and east of Lake Corangamite and south of Skipton. Lakes and swamps occur in volcanic craters, in depresssions caused by lava collapse (both in stony rises and elsewhere) and where drainage patterns have been interrupted particularly along the edges of lava flows (Currey 1970). Lunettes, parna dunes and lacustrine deposits formed during the retreat of a much larger Lake Corangamite (Currey 1963) and by present lakes (Gill 1963) are common. Over much of the plains drainage is internal, either to lakes, swamps or to ground water and has been greatly modified by drainage works.

Climate

The region's climate as it affects this study including wetland maintenance is taken from Central Planning Authority (1956), Bureau of Meteorology (1959), Department of National Development (1966), Bureau of Meteorology (1968), Hounam & Powell (1964) and Cameron (1979).

Rainfall distribution is mainly influenced by orographic features, namely the western highlands and Otway Ranges where rainfall is increased; the latter cast a rain shadow over the lowlands to the west of Port Phillip Bay. Median (10 and 90 percentile) annual rainfall is 900 to 1800 mm (800 to 1800 mm and 1200 to 2400 mm) in the Otway Ranges, 700 to 900 mm (600 to 800 mm and 800 to 1200 mm) on the coastal plains, 700 to 1000 mm (400 to 600 mm and 800 to 1200 mm) in the western highlands, 500 to 700 mm (400 to 500 mm and 600 to 800 mm) throughout the western plains and is 400 to 500 mm (300 to 400 mm and 600 to 800 mm) in the rain shadow to the west of Port Phillip Bay. Annual variation in rainfall is amongst the lowest in Australia (Cameron 1979). January is the driest month throughout the area; falls in the wettest months on the eastern lowlands (September and October) and elsewhere (July, August and September) exceed January falls by 1 to 2 and 2 to 3 times respectively.

Temperatures range from January average maxima of 21 to 27°C (minima 10 to 16°C) to July average maxima of 5 to 10°C (minima 1 to 4°C inland and 4 to 10°C near the coast). Frost can be expected on fewer than 5 days per year close to the coast and on up to 15 days per year inland and on higher parts.

Evaporation decreases towards the sea and towards increasing altitude; it ranges from less than 150 mm per year in the Otway Ranges to just under 1000 mm per year on the plains where it is highest in January (110 to 150 mm) and lowest in July (25 to 40 mm). Evaporation exceeds rainfall from September until May and this is reflected in both the patterns of run-off which result in stream flows and in the occurrence of periods of non-effective rainfall (i.e. falls insufficient to start germination and maintain growth). Over most of the plains, where Berrybank (30 years of records) can be used as an example, non-effective falls have been recorded in most months in the six month period April to September; however, these events have not been consecutive. From the spring months onward periods of non-effective rainfall become both more frequent and protracted. In the six month period October to March, 2, 3 and 4 consecutive months of non-effective falls have occurred in 93%, 66% and 33% of years respectively. Close to the coast and in the ranges the frequency of non-effective falls during summer decreases e.g. at Beech Forest (51 years of records) 2 and 3 months of non-effective falls have occurred in only 15% and 2% of years respectively.

Hydrology

The Werribee (gauged mean annual discharge of 78×10^3 ML from a catchment of 1100 km²), Moorabool (70×10^3 ML from 1100 km²) and Yarrowee (92×10^3 ML from 870 km²) Rivers and Mount Emu Creek (67×10^3 ML from 1240 km²) rise in the western highlands and the Barwon (139×10^3 ML from 1040 km²), Curdies (130×10^3 ML from 780 km²) and Gellibrand (135×10^3 ML from 560 km²) Rivers rise in the Otway Ranges. Smaller streams which drain the southern slopes of the Otways include the Aire (27×10^3 ML from 25 km²) and the Carlisle Rivers (37×10^3 ML from 77 km²) (Bibra & Riggs 1971).

Stream flows are highest in August or September and are lowest, often reaching zero, in January, February or March. Floods can occur throughout the year but are least frequent during summer. Flood frequencies and summer flows have been reduced in most rivers by the construction of dams and the subsequent diversion of irrigation and urban water.

On the plains countless minor drains have either eliminated or limited the extent of swamps and lakes. Major drains constructed in the 1950s control the levels of Lakes Colac and Corangamite, diverting excess water to the Barwon River and preventing a recurrence of the extensive expansion these lakes underwent following successive years of above average rainfall during the 1950s.

Seasonal variation (Bibra & Riggs 1971), type of basalt substrate (Maddocks 1967) and various catchment to surface area ratios and throughflows combine to produce lakes and swamps of a very wide range of salinities (e.g. Williams 1964, Bayly & Williams 1966). The geochemistry of waters in the region is discussed by Maddocks (1967) and detailed studies which include seasonal changes of individual basins have been made (e.g. Pollard 1971a, Timms & Brand 1973, Walker 1973, Geddes 1976, Timms 1976, Williams & Buckney 1976).

METHODS

Wetland Distribution

All wetlands and drained areas larger than 1.0 ha (excluding river flats inundated during floods) were located from aerial photographs (Division of National Mapping and Department of Crown Land and Survey, 1:85000 enlarged ×2, flown 1961 Ballarat and 1976 Melbourne map sheets and 1:33000 flown 1975-77 for the remainder), from topographic maps and during ground surveys between July 1978 and November 1980. Water source and regime were determined, plant communities identified and areas calculated by planimeter measurement from aerial photographs.

Wetland Classification

Water regime and salinity were used for definition of wetland categories while subcategories were based on vegetation important in determining waterbird usage. Wetlands were classified as fresh if salinity remains below 3000 parts per million (ppm) (Williams 1964) for the greater part of the period of inundation. Changes in depth and area (e.g. Lake Corangamite, Currey 1963, Parliamentary Public Works Committee 1965) resulting from long term trends in the amount of rainfall have been ignored and the areas calculated and categories assigned using conditions prevailing during this study.

Sewage oxidation basins have not been included in previous surveys (Corrick & Norman 1980, Corrick 1981); however, in the present study area, along with salt evaporation basins, their area is substantial. Individual basins in these systems are small (often <1 ha) and collectively show a wide range of chemical compositions and limnological development and could be assigned individually to one of several wetland subcategories (e.g. salt evaporation basins range in salinity from sea water to saturation and thus cover subcategories 6.1, 6.5 and 7.1). The condition of the individual basins may also change at anytime with changes in management practices. Classification of individual basins was considered to be inappropriate; the systems were considered as single wetlands outside the category system (Tables 2 and 3) but their distribution and waterbird use have not been shown.

The diagnostic salinities, water regimes and vegetation of all wetland categories and subcategories found are summarized in Table 1. Subcategories not described by Corrick and Norman (1980) or Corrick (1981) are described below.

Red Gum-dominated (Subcategories 2.3 and 3.5)

Red Gum (*Eucalyptus camaldulensis* Dehnh.)

TABLE 1
CHARACTERISTIC DEPTH, DURATION OF INUNDATION OF THE WETLAND CATEGORIES AND TYPICAL VEGETATION OF WETLAND SUBCATEGORIES IN THE STUDY AREA

Category	*Depth* (m)	*Duration of inundation*	*Subcategories*	*Typical vegetation*
FRESHWATER				
2, Meadows	<0.3	<4 months	.1 Herb-dominated	Annual moist soil species
			.3 Red Gum-dominated	*Eucalyptus camaldulensis*
			.4 Lignum-dominated	*Muehlenbeckia cunninghamii*
3, Shallow marshes	<0.5	<6 months	.1 Herb-dominated	Annual moist soil and aquatics
			.3 Cane Grass-dominated	*Eragrostis australasica*
			.4 Lignum-dominated	*M. cunninghamii*
			.5 Red Gum-dominated	*Eucalyptus camaldulensis*
4, Deep marshes	<2	12 months	.2 Reed-dominated	*Phragmites australis, Typha* sp. *Scirpus validus*
			.3 Sedge-dominated	*Lepidosperma longitudinale*
			.4 Rush-dominated	*Eleocharis sphacelata*
			.5 Open water	Submerged aquatics with moist soil annuals in the littoral zone.
			.6 Cane Grass-dominated	*Eragrostis australasica*
			.7 Lignum-dominated	*M. cunninghamii*
5, Permanent open water	>0	permanent	.1 Shallow (<3 m)	Submerged aquatic species, emergent species in the littoral zone.
			.2 Deep (>3 m)	Submerged aquatics[1]
			.3 Impoundment	Submerged aquatics with emergent species in the littoral zone[2]
SALTWATER				
6, Semipermanent	<2	<8 months	.1 Salt pan	*Lepilaena* spp. *Ruppia* sp[3].
			.2 Salt meadow	Halophytes with *Ruppia* sp. and *Lepilaena* spp. in shallows
			.3 Salt flats	Dense ground cover of halophytes
			.5 Hypersaline lakes	none
7, Permanent	>0	permanent	.1 Shallow (<3 m)	*Ruppia* spp. *Lepilaena* spp.
			.2 Deep (>3 m)	*Ruppia* spp. *Lepilaena* spp.
			.3 Intertidal flats	*Zostera* spp. various alga, none in places[4]

[1] Reduced by turbidity and depth. [2] Depends on grazing. [3] No vegetation when dry. [4] Sand flats are usually devoid of vegetation.

woodland up to 20 m tall occurs on both freshwater meadows and shallow freshwater marshes. Associated vegetation is similar to herb-dominated subcategories but Cane Grass (*Eragrostis australasica* (Steud.) Hubbard) and Lignum (*Muehlenbeckia cunninghamii* (Meissn.) Mueller) may also occur. Mature trees, both in wetlands and on higher ground, provide nest hollows for waterfowl; however, grazing and cultivation prevent regeneration so that mature trees are not being replaced.

Cane Grass-dominated (Subcategories 3.3 and 4.6)

Cane Grass has upright stems (<5 mm in diameter) up to 1.4 m high which range from scattered tussocks to continuous extensive stands in which the stems become progressively more tangled if flooding persists for several seasons. Grazing reduces stems to ground or water level and prevents regrowth until after flooding. In highly turbid water associated species may be absent.

Lignum-dominated (Subcategories 2.4, 3.4 and 4.7)

Lignum forms dense tangled bushes (up to 2.5 m high and 3 m in diameter) in water up to 1 m deep. Although the stems are woody, persistent grazing will eventually break these down and along with cultivation will remove bushes entirely. Both Red Gum and Cane Grass are often associated with Lignum which also occurs as scattered bushes above the shoreline of permanent open waters and persists in drained areas which have not been cultivated.

Hypersaline lakes (Subcategory 6.5)

In lakes of this category salinity only drops below 50 000 ppm in exceptionally wet seasons. The water usually reaches saturation each year as the water level recedes. Smaller basins may be 3 m deep but large areas are shallow (<0.4 m) so that summer drying occurs. Rooted aquatic plants may be present for the short period when salinity is low but growth is reduced as salinity rises. Zooplankton, particularly *Parartemia zietziana*, which will hatch in salinities to 202 000 ppm and survive almost to saturation (Geddes 1976), are abundant.

WATERBIRD DISTRIBUTION AND ABUNDANCE

When wetlands were visited throughout the study period waterbirds were either counted on the whole, or part, of each wetland; alternatively only the species present were recorded. Large wetlands were visited several times although usually only one complete count of waterbirds present was made on each. The counts, 780 in all, were used to indicate habitat preferences, provide

TABLE 2
NUMBER OF WETLANDS OF EACH CATEGORY AND NUMBER OF AREAS OF EACH WETLAND SUBCATEGORY IN EACH WETLAND SIZE RANGE

Category/subcategory	*Number of wetlands in the following size (ha) ranges*					*Total number*	
	1-5	6-10	11-25	26-100	>100	*Subcategory*	*Category*
2 Freshwater meadow							
.1 Herb-dominated	237	80	44	8	1	370	
.4 Lignum-dominated			1			1	
Number of wetlands	237	80	45	8	1		371
3 Shallow freshwater marsh							
.1 Herb-dominated	154	34	33	25	1	247	
.3 Cane Grass-dominated	1		3			4	
.4 Lignum-dominated	1		1	1		3	
.5 Red Gum-dominated			1			1	
Number of wetlands	156	34	37	26	1		254
4 Deep freshwater marsh							
.1 Shrub-dominated		1				1	
.2 Reed-dominated	1	1			2	4	
.3 Sedge-dominated	1	1	2	1	1	6	
.4 Rush-dominated	4	2		1	1	8	
.5 Open-water	47	2	14	13	5	81	
.6 Cane Grass-dominated			1	3	2	6	
.7 Lignum-dominated				1		1	
Number of wetlands	52	5	16	13	6		92
5 Permanent open freshwater							
.1 Shallow	2	2	1	8	9	22	
.2 Deep	1			1	2	4	
.3 Impoundment	318	25	13	8	10	374	
Number of wetlands	321	27	14	16	19		397
6 Semipermanent saline							
.1 Salt pan	101	41	36	32	10	220	
.2 Salt meadow	19	16	11	16	5	67	
.3 Salt flats	3	3	6	13	4	29	
.4 Hypersaline lake	1	2	6	3	3	15	
Number of wetlands	119	50	46	38	14		267
7 Permanent saline							
.1 Shallow	2	4	5	10	16	37	
.2 Deep		1			5	6	
.3 Intertidal flats			1	1	2	4	
Number of wetlands	2	4	6	11	18		41
Salt evaporation basin					4		4
Sewerage oxidation basin	6	3	1		1		11
Totals	893	203	165	112	64		1437

a species list (common names according to RAOU 1978) for each category and subcategory and enable both the frequency of occurrence of species to be compared and the regional significance of concentrations to be gauged.

During August, September and October 1978 and September 1979 records were kept of sightings of waterbirds not on wetlands included in the study. Observations aided by 10×50 binoculars were made from a vehicle over 1100 km of roads through open farmland between Geelong and Colac and near Ballarat. Approximately 0.3 km on each side of the road was covered except where hedges, trees and buildings obscured views.

So that seasonal changes in wetland area and waterbird use and populations could be monitored on a quantitative basis 135 wetlands (or parts of large wetlands) of known area between 38°00′ and 38°30′S and 143° to 144°E were selected and counts made in March, July and October 1980. Buoys, stakes and natural features were used to mark site boundaries and areas were calculated from aerial photographs, by triangulation and by rangefinder measurements. Observations were aided by 10×50 binoculars and 25×60 telescope. The area of water was estimated each month.

Analysis of Waterfowl Banding Data

Ducks have been banded in Victoria since 1950, 81% at the Wildlife Research Station at Lara (38°01′S 144°25′E). The distribution of the returns of bands from ducks shot during open seasons between 1951 and 1980 has been plotted on a 10′ grid of the area and the number compared with recoveries from elsewhere in the state.

RESULTS

Wetland Distribution

During this study 1437 wetlands (Table 2) totalling 72 500 ha (Table 3) were located, including 1680 ha of sewage oxidation and 2180 ha of salt evaporation systems (which were not categorized). Impoundments

Table 3
Area of Wetland Categories and Subcategories in Wetlands of Various Size Ranges

Category/subcategory	*Area (ha) of wetlands in the following size (ha) ranges*					*Total area*	
	1-5	6-10	11-25	26-100	>100	*Subcategory*	*Category*
2 Freshwater meadow							2410
.1 Herb-dominated	630	620	700	323	123	2400	
.2 Lignum-dominated			16			16	
3 Shallow freshwater marsh							2540
.1 Herb-dominated	368	261	557	1060	190	2440	
.3 Cane Grass-dominated	5		30			35	
.4 Lignum-dominated	3		20	26		49	
.5 Red Gum-dominated			16			16	
4 Deep freshwater marsh							2320
.1 Shrub-dominated		9				9	
.2 Reed-dominated	1	2			365	368	
.3 Sedge-dominated	3	7	30	43	69	152	
.4 Rush-dominated	11	12		30	66	119	
.5 Open-water	75	15	213	580	540	1420	
.6 Cane Grass-dominated			8	36	148	192	
.7 Lignum-dominated				53		53	
5 Permanent open freshwater							16100
.1 Shallow	9	16	19	376	11400	11800	
.2 Deep	4			30	680	710	
.3 Impoundment	580	187	212	416	2180	3580	
6 Semipermanent saline							8080
.1 Salt pan	239	261	460	1260	1540	3760	
.2 Salt meadow	43	111	86	279	385	904	
.3 Salt flats	7	12	82	500	1220	1820	
.5 Hypersaline lake	3	15	98	117	1360	1590	
7 Permanent saline							37200
.1 Shallow	3	23	85	660	14400	15200	
.2 Deep		5			20900	20900	
.3 Intertidal flats			15	57	1020	1090	
Salt evaporation basin					2180		2180
Sewerage oxidation basin	18	27	19		1620		1680
Total	2000	1580	2670	5850	60400		72500

TABLE 4
NUMBERS AND AREA (ha) OF WETLANDS DESTROYED BY DRAINAGE WORKS AND THE AREA LOST AND THE AREA OF OTHER WETLAND CATEGORIES CREATED BY PARTIAL DRAINAGE

Category	*Destroyed Area* (No)	*area lost*	*Reduced or altered to:* *FM*	*SFM*	*DFM*	*POFW*	*SPS*	*PS*	*Total affected*	*net lost**
Freshwater meadow	1660 (162)	67	31 (6)						1760	390
Shallow freshwater marsh	5090 (228)	3860	1020 (137)	133 (16)		4 (1)			10110	9340
Deep freshwater marsh	2280 (16)	1690	166 (9)	408 (13)	16 (1)		4 (1)		4560	4540
Permanent open freshwater	590 (2)	1100		36 (2)	13 (1)		670 (7)		2410	2410
Semipermanent saline	53 (5)	278					1100 (10)		1430	−1390
Permanent saline	0	940	153 (1)				1050 (4)	560 (1)	2890	2330
Total area (number)	9670 (413)	7940	1370 (153)	767 (31)	29 (2)	4 (1)	2820 (22)	560 (1)	23160	17610

*total affected less area of category formed by partial drainage of other categories.

(374) and herb-dominated freshwater meadows (370) are the most numerous subcategories but are on average small in area (9.6 ha and 6.5 ha respectively). Other subcategories which are numerous include herb-dominated shallow freshwater marshes (247 average 9.9 ha) and salt pans (220 average 17.1 ha). These four subcategories account for 85% of the wetlands in the region studied but only 18% of the area of wetland in it. Permanent saline wetland (37 200 ha) and shallow and deep permanent open freshwater (12 500 ha), account for 54% and 24% of the area and 3% and 2% of the number of wetlands respectively. In all categories except permanent saline the number of wetlands in the various size ranges decreases with increasing size. For freshwater meadows and shallow freshwater marshes the largest area is in the 11-25 and 26-100 ha size classes; for all other categories the > 100 ha class contains the greatest area even though it contains the fewest wetlands. Overall, 62% of wetlands and 3% of the area is in wetlands 1-5 ha in area while 4% of wetlands and 82% of the area is contained in wetlands > 100 ha in area.

Six wetland subcategories each occur at 4 or fewer sites and total less than 100 ha. A further 3 subcategories occur at 4 or fewer sites but their area is greater than 100 ha. These nine subcategories, together with sedge and Cane-Grass-dominated deep freshwater marshes and hypersaline lakes are restricted to 5 or fewer 10′ grids (Fig. 2). Natural freshwater wetlands (52% of the total wetland area) are found throughout the lowlands and are absent from the ranges; saline wetlands are found on the basalt plains and along the coast. The most widespread subcategories are also the most numerous (i.e. freshwater meadows, shallow freshwater marshes and impoundments).

Drainage works of various forms have destroyed or altered 623 wetlands which covered 23 160 ha (Table 4); of these 413 (9670 ha) have been lost completely with freshwater meadows 162 (1660 ha), shallow freshwater marshes 228 (5090 ha) and deep freshwater marshes 16 (2280 ha) having decreased most. The net result, allowing for the area of some categories created by partial drainage of others, is that 390 ha of freshwater meadow, 9340 ha of shallow freshwater marsh, 4540 ha of deep freshwater marsh and 2410 ha of permanent open freshwater have been lost. Only the area of semipermanent saline wetland has increased since settlement (by 1390 ha). These changes, when compared to the area present before European settlement, represent a loss of 14% of the area of freshwater meadow, 79% of shallow freshwater marsh, 66% of deep freshwater marsh, 16% of permanent open freshwater, 6% of permanent saline wetland and an increase in the area of semipermanent saline wetland of 17%.

SEASONAL CHANGES IN WETLAND AREA

Changes in area of the count sites visited in March, July and October 1980 (Table 5) show that subcategories with permanent water show little seasonal change in area while salt and freshwater meadows, shallow freshwater marshes and salt pans will dry during summer and fill during winter. Drying rate depends on rainfall, temperature, catchment area, bottom type and contour. Wetland categories and subcategories not included in the count sites, particularly various subcategories of deep freshwater marshes, would show similar variation to open water areas of this category. In impoundments the seasonal fluctuations are increased by diversions of water and tidal flats vary in extent according to the lunar cycle.

WATERBIRD DISTRIBUTION AND ABUNDANCE

During the study 86 species of waterbird were recorded (Table 6, Appendices 1 & 2) and a further 24 have been recorded by other authors. The five most abundant species on each of the wetland subcategories (28 species in all) surveyed during counts in March, July and October 1980 are listed in Table 6. Wetland subcategories used by less abundant but regularly seen

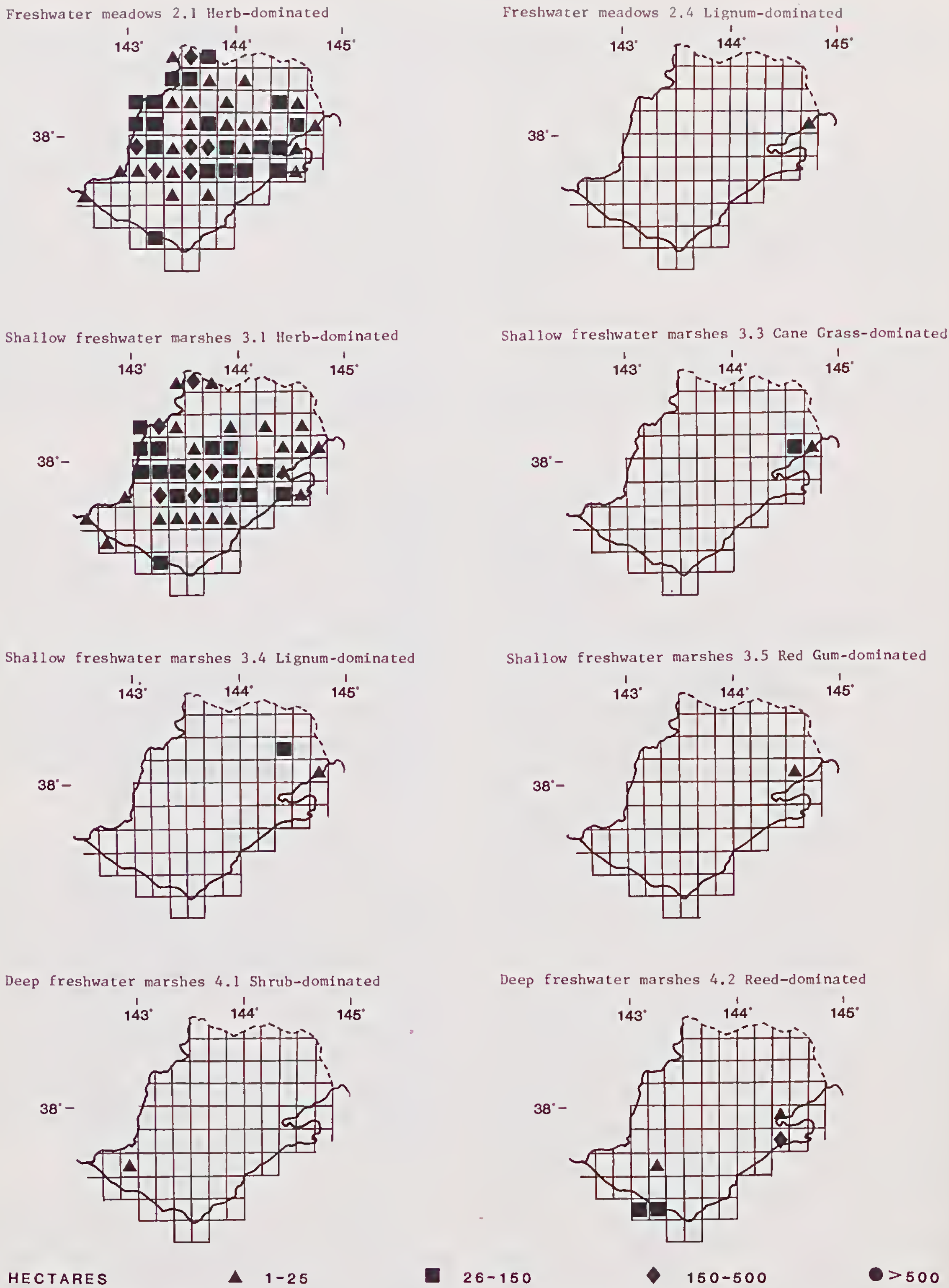

Fig. 2 – The distribution (plotted on a 10′ grid) of the area (ha) of each wetland subcategory of the study area.

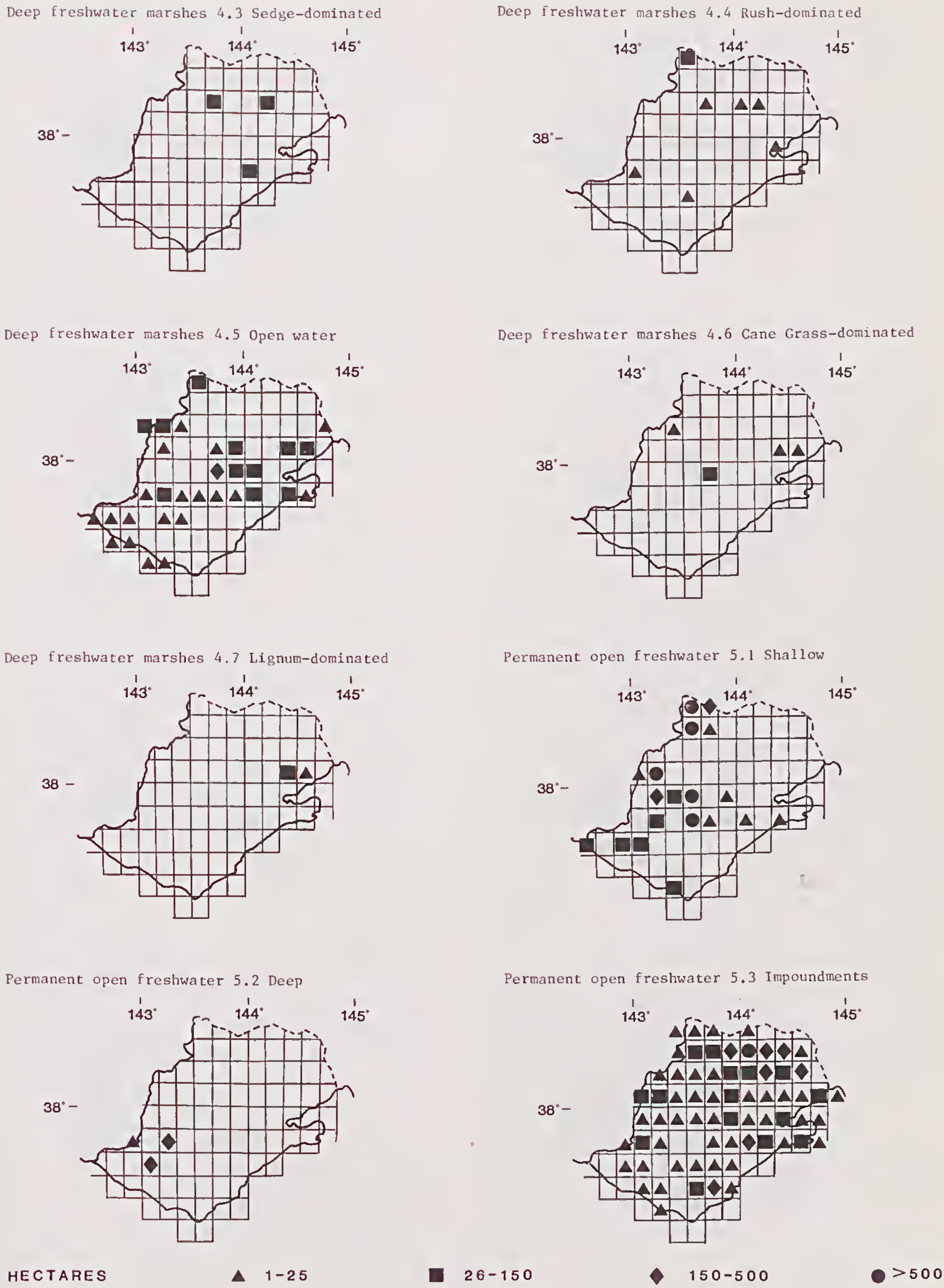

Fig. 2(*continued*)

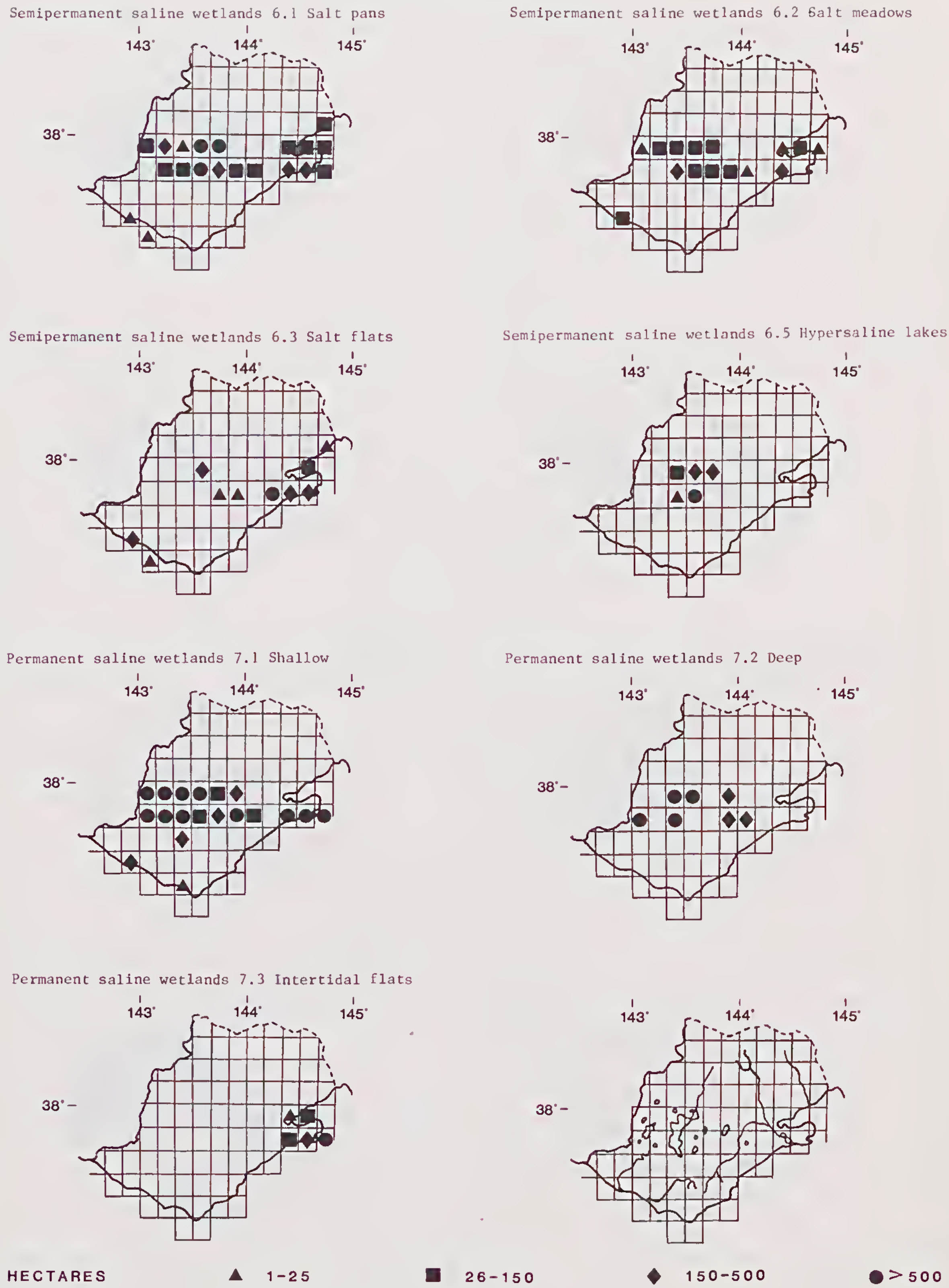

Fig. 2(*continued*)

species are presented in Appendix 1 and Appendix 2 lists the remaining rare species, which either occur regularly in very low numbers, are misplaced nomadic or migratory species (e.g. various sandpipers, Garganey Teal) or are more common on other habitats of the region (e.g. Hooded Plover—ocean beaches, Black-faced Shag—offshore waters).

The 780 counts made of waterbirds during ground surveys have been used to indicate subcategories utilized by species listed in Appendix 1. The more abundant species (Hoary-headed Grebe, Black Swan, Masked Lapwing, Australian Shelduck, Silver Gull, Table 6) were also the most frequently recorded occurring on a wide variety of wetlands. The counts also indicate species with particular habitat preferences, thus more than 50% of the records of some species came from a single wetland category, e.g. Latham's Snipe—freshwater meadow; Brolga—shallow freshwater marsh; Marsh Harrier, Dusky Moorhen and Purple Swamphen—deep freshwater marsh; Banded Stilt—hypersaline lakes and Great Crested Grebe, Pelican, Pied Cormorant, Great Egret, Chestnut Teal, Blue-billed Duck and Freckled Duck—permanent saline wetlands.

Data from counts conducted in March, July and October 1980 (Table 6) show the distribution of species and numbers amongst the subcategories studied. Hoary-headed Grebe, Black Swan, Shelduck, Grey Teal, Coot, Masked Lapwing and Silver Gull are abundant on most categories while other species, e.g. Great Crested Grebe, Blue-billed Duck, Dusky Moorhen and Purple Swamphen, are restricted to only a few; shorebirds are obviously absent from deep permenant open freshwater and cormorants from hypersaline lakes. Count sites on wetlands with shallow permanent water have the highest density of birds (means of 8-24 birds/ha) and the most species (means 4-7 species/visit) while sites on seasonal wetlands have lower population densities (means from 1.5-13.2 birds/ha) and fewer species (1.5-4 species/visit). On all subcategories the 5 most abundant species accounted for more than 70% of all birds/ha and in many cases for more than 95% of this total. Observations suggest that intertidal flats, sewage oxidation and salt evaporation systems, a subcategory and habitats not included in the 3 counts during 1980, also carry comparatively high densities of birds. The results of detailed surveys of these habitats are provided by Tarr (1952), Morgan (1954), Watson (1955), Wheeler, W. R. (1955), Barkla (1978) and personal communication from members of the Australasian Wader Studies Group in 1981.

The numerical distribution of all species across the wetlands of the area cannot be considered in detail here; however, it is clear that the shallow lakes (salinities <50 ppt), which comprise a large proportion of the total wetlands area (Table 3) support a large proportion of the populations of some non-breeding waterbirds. The seasonal and annual changes which occur in these lakes can provide conditions particularly favourable to a species and large concentrations which are not necessarily annual events can occur. Wetlands at which regionally significant concentrations of non-breeding birds were recorded include:

Lake Corangamite (southern half)—7500 Coot, 1400 Great Crested Grebe, 8200 Black Swan, 100 Chestnut Teal on 30 November 1979.

Lake Corangamite (northern half)—14 000 Hoary-headed Grebe, 1900 Musk Duck on 10 April 1979 and 650 Freckled Duck on 26 August 1980 (Corrick 1980).

Lake Rosine—6000 Pink-eared Duck, 3000 Blue-billed Duck 25 July 1979.

Lake Murdeduke—19 000 Coot on 9 April 1979.

Lake Gnarpurt—900 Musk Duck 31 April 1979.

Lake Becac—11 000 Banded Stilt 23 February 1979, 1000 Whiskered Tern on 17 October 1979.

Lake Bookar—7000 Hoary-headed Grebe on 26 June 1979.

An unnamed shallow freshwater marsh at 38°08′S 143°45′E—300 Avocet on 18 November 1979.

Seasonal changes apparent in Table 6 may be due to changes in the area of available habitat (see Table 5), or to arrival and departure of migratory species (e.g. Sharp-tailed Sandpiper and Whiskered Tern). Nomadic species (Pink-eared Duck, Hardhead, Grey Teal and Black Swan) may also show numerical changes related to climate and wetland conditions outside the study area, which are not regular seasonal events, and finally the effect of the duck shooting season may also modify populations. The long term variability of numbers of a nomadic species, Grey Teal, is shown by Figure 3 (see also Morgan 1954). The population is generally low from July to December inclusive and high with greater variation from year to year for the remainder of the year.

During roadside counts of waterbirds (not on wetlands included in the study), 494 sightings of 31 species were made, 222 sightings of 25 species were on farm dams and ponds <1.0 ha in area. In all 953 dams were checked and of these 158 (17%) had waterbirds on or close by; Masked Lapwing (on 44 dams), Pacific Heron (on 30), White-faced Heron (on 27), Hoary-headed Grebe (on 26) and Black Duck (on 22) were seen most frequently. Of the 158 dams with waterbirds 73% had only one species present, 18% had two, 5% three, 3% four and 1% five species. Away from dams the most frequently seen species were White-faced Heron (73 sightings), Masked Lapwing (41), Straw-necked Ibis and Pacific Heron (36), Silver Gull (35) and Australian Shelduck (22). Of the common species on dams only two, Black Duck and Hoary-headed Grebe, were not seen more frequently away from dams.

The habitats used by breeding waterbirds are often entirely different and often distant from the non-breeding records given previously. Time did not permit detailed searches of each category of wetland for nests so except for colonial nesting species relatively few breeding records were obtained. However, the dependence of some species on particular conditions or vegetation for successful breeding are apparent. Some species breed throughout the area, e.g. White-faced Heron which next in trees away from water, and Masked

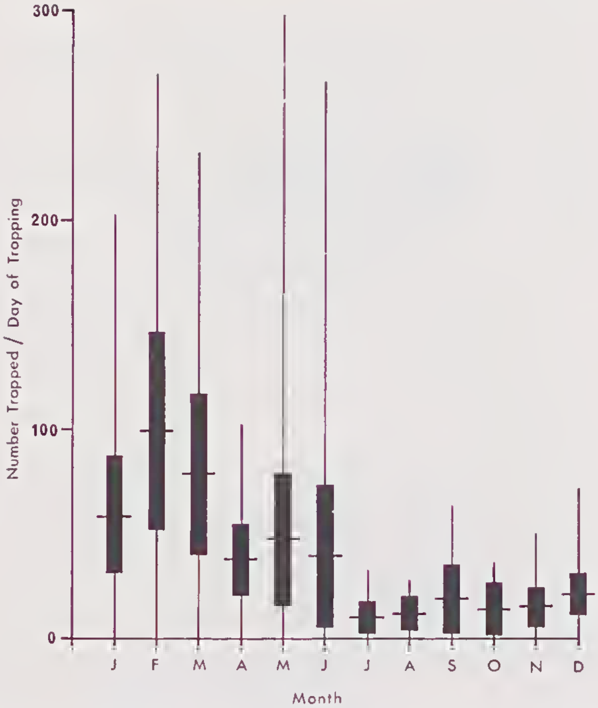

Fig. 3—The range (vertical line), mean (horizontal line) and 95% confidence limits of the number of Grey Teal caught per day of trapping each month between 1951 and 1977 at Serendip Wildlife Research Station 38°01'S and 144°25'E.

Plover which nest on the ground around wetlands and in pasture. Some species are restricted to either particular wetland categories (e.g. Brolga to freshwater meadows and shallow freshwater marshes, Black-winged Stilt to freshwater and saltwater meadows, Blue-billed Duck to deep freshwater marshes (Wheeler, J. R. 1953) and Bittern to deep freshwater marshes); or utilize non-wetland habitats (e.g. Shelduck use tree hollows, Black Duck use long grass and dense vegetation and Pied Oystercatcher and Red-Capped Plover use beaches and adjacent dunes). Finally several species nest colonially (e.g. Straw-necked and Sacred Ibis use extensive reed beds in Reedy Lake near Geelong; these species of ibis with Pelican, Glossy Ibis, Black Swan, Pied and Great Cormorant, Silver Gull and Gull-billed Tern use islands in wetlands; Pied Cormorant use trees on an island in Swan Bay and on the Melbourne Sewage Farm at Werribee and Fairy Terns use large areas of exposed sand above high tide line). The continued success of these colonies is dependent on the continued seclusion of the sites both from predators and disturbance by man and the maintenance of appropriate nesting substrates.

Analysis of Waterfowl Banding Data

Bands have been returned from all but one (in the Otway Ranges) of the 10' grid squares entirely within the area (Fig. 4) and all but seven partly in the area, 5 of which are mainly ocean, 1 outer suburban, and the last forested ranges along the northern boundary. Recoveries of all species are concentrated in squares about the main banding location at Serendip (Table 7), which include tidal flat, semipermanent saline wetlands, salt evaporation and sewage oxidation systems along the western shores of Port Phillip Bay and semipermanent and permanent saline wetlands and deep freshwater marshes at the mouth of the Barwon River and in the four 10' grid squares which include Lakes Corangamite, Martin and Colac. A higher proportion of bands from Black Duck, than from other species, have come from 10' squares without large wetlands, particularly in the northeastern part of the area. Grey Teal have come from more squares (73) and a higher proportion have come from the grid squares containing Lake Murdeduke and Modewarre than have returns of other species. Chestnut Teal have come from only 32 squares, more along the southern coast and few in the ranges, while most returns

Table 5
The Mean and Standard Error (SE) of the Area (Expressed as a % of the Total Possible Area) and the Number of Sites at Which Waterbird Counts were made in March, July and October 1980

	March		*July*		*October*		
Category	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*number*
Freshwater meadow	0		44	8	63	8	27
Shallow freshwater marsh	0		58	11	69	10	19
Deep freshwater march	65	14	96	2	98	2	9
Permanent open freshwater							
Shallow	91	5	95	2	96	3	9
Deep	100	0	100	2	100	0	2
Semipermanent saline							
Salt pan	12	6	92	3	96	3	29
Salt meadow	0		71	12	71	12	9
Hypersaline lakes	43	16	99	6	100	0	8
Permanent saline wetland							
Shallow	72	7	86	5	97	2	24
Deep	0		100		100		

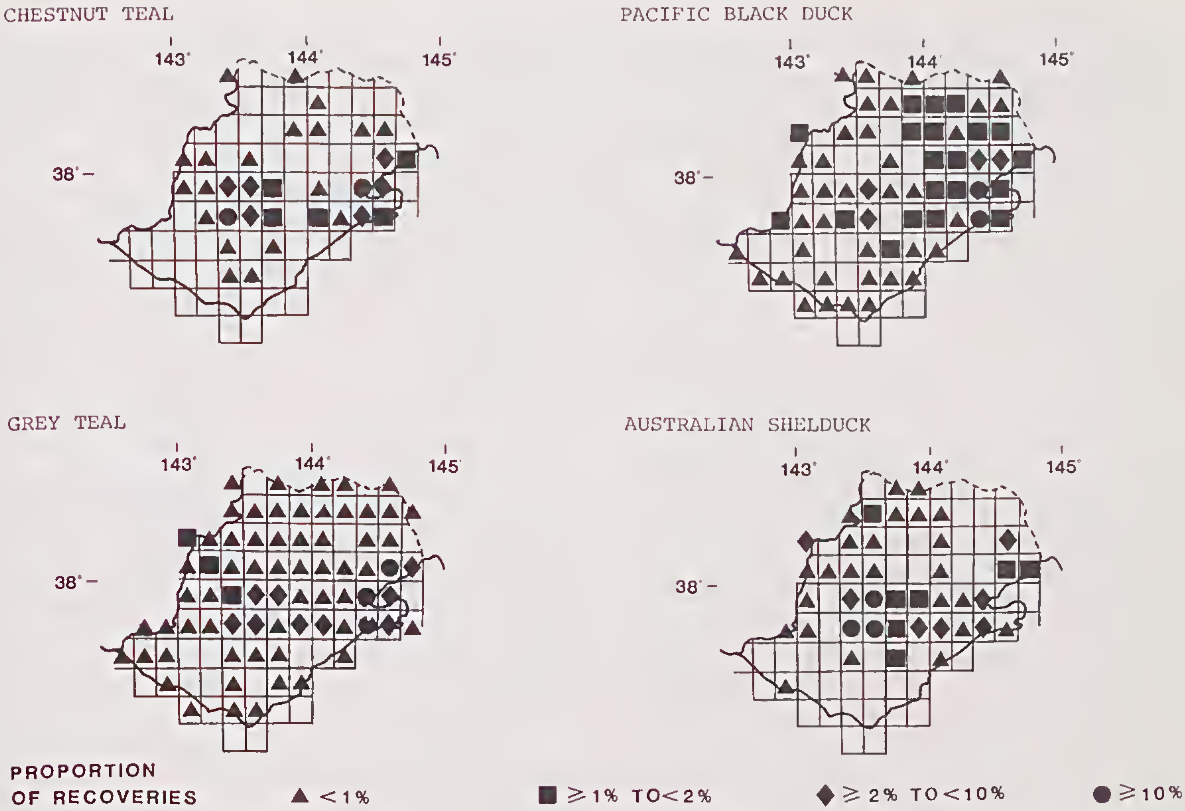

Fig. 4—The distribution of band recoveries from Australian Shelduck, Pacific Black Duck, Grey Teal and Chestnut Teal by shooting in 10′ grid squares covering the study area. Recoveries between 1951 and 1980 are included. The number recovered in each square is displayed as a proportion of the total number recovered from each species in the study area.

of Australian Shelduck, few of which were banded at Serendip, are from the western plains.

DISCUSSION

The total area of wetland including sewage oxidation and salt evaporation systems located in this study, is 72 500 ha, which compares with 72 200 ha and 75 900 ha located in similar surveys in Gippsland and South Gippsland (Corrick & Norman 1980, Corrick 1981); however, there are many more wetlands (1437 cf. 320 and 202) and the proportions of various categories are different. In South Gippsland, for example, 91% of the wetland area is intertidal flats while here only 1.6% is of that subcategory. Around the Gippsland Lakes shallow and deep permanent saline wetlands comprise respectively, 13% and 21% of the total while in this study they comprise 22% and 31%. The proportion of freshwater wetland is higher (35% of total cf. 33% and 3%) and the area of freshwater meadow and shallow freshwater marsh is some four times higher than in the previous studies.

As in the other areas studied there have been widespread changes in wetland area since European settlement. These changes include the large number of wetlands which have been drained, the 374 impoundments spread almost throughout the region and the extensive sewage (1680 ha) and salt evaporation (2180 ha) systems on Port Phillip Bay. In all 34% of the original area of freshwater wetland has been lost, 14% of freshwater meadow, 79% of shallow marshes, 66% of deep marshes and 16% of permanent open water. These changes in area include 37% of the number of wetlands. These losses are not as severe as those in South Gippsland where 95% of the area of freshwater wetlands has been lost but worse than around the Gippsland Lakes where 22% has been lost. As in other parts of the state little saline wetland has been lost.

The impact of these changes on waterbird populations is difficult to assess. Certainly the large number of impoundments and increased area of cleared land have benefited a few species (e.g. Hoary-headed Grebe, Ibis and White-faced Heron) enabling them to occur more widely. The large populations of migratory waders along the western shores of Port Phillip Bay are probably due to a combination of factors including the increased productivity of intertidal flats due to outfalls of treated sewage and the presence of adjacent sewage and salt works ponds which enable migratory waders to feed for longer periods each day than is possible on intertidal flats alone. Although the sewage ponds and impoundments are used by flocks of waterfowl it is unlikely that the populations of these species have benefited

TABLE 6

ABUNDANCE OF BIRDS ON WETLAND CATEGORIES INCLUDED IN COUNTS IN MARCH (M), JULY (J) AND OCTOBER(O) 1980. Birds are ranked in order of abundance (birds/ha) from 1 (highest) to 10 (lowest). The table includes the 5 most abundant species from each category in each month and indicates the rank (or its presence (+) at ranks over 10) on the other categories and in other months. The number of sites, the number of species and the total number of birds/ha is also given. The category and subcategories are listed in full in Table 1.

Species	2.1			3.1			4.5			5.1			5.2			6.1			6.2			6.5			7.1		
	M	J	O	M	J	O	M	J	O	M	J	O	M	J	O	M	J	O	M	J	O	M	J	O	M	J	O
Great Crested Grebe											+			2	1		+	+							+	+	7
Hoary-headed Grebe		9	+		+	7	3	2	3	3	2	2	1	1	2	+	7	3					4	3	2	3	4
Little Black Cormorant									8	10	10			4	4			+							8		+
Little Pied Cormorant										+	+			3			+								+	+	
White-faced Heron		3	10		9	3	9			+						5	+	+			+	5			+		
Straw-necked Ibis		+	1			6										7		+			+						
Yellow-billed S'bill											7					2	+										
Black Swan		1	2		7	4	4	7	4	2	+	5	2		6	6	3	1		1	5	6		1	10	7	3
Australian Shelduck		8	8		+	+	7			+			4	5			4	8		2		1	2	5	7		+
Pacific Black Duck		6			4		6	6		+	+		6				6										
Grey Teal			5		3		10	4	9	9	5	+				9	1	2			7				3	5	8
Australasian Shoveler			+		10	+		10	5	7	6	9						+			+				+	+	+
Pink-eared Duck										5		+				3		+							+	2	2
Hardhead			+			8		8	2	+	+	3						9							+		5
Blue-billed Duck										6	4	8					+								+	10	
Musk Duck							+			+	9			6	3										4	4	6
Dusky Moorhen							5	5	+																		
Purple Swamphen		+	+		1	2	2	3	6									+									
Eurasian Coot		+			6	+	1	1	1	1	1	1	3		5	+	2	+			6			6	1	1	1
Masked Lapwing		4	9		5	9	8	9	+		+					1	5	7		4	8	4	5		6	+	+
Red-capped Plover					8	+		+	+	+	+	+				+	8			3			6		+	+	+
Black-winged Stilt			4			5				+		+						10			4				+		
Red-necked Avocet								+		8						10	9	6			9		1		+		
Sharp-tailed Sandpiper			+			10		+	+	+		7						5			2				+	+	+
Red-necked Stint		7						+		+	+	6				8			2		3				+	6	9
Curlew Sandpiper		5						+										+			+						
Silver Gull		2	6		2	+			+	4	3	+	5				10	+	4	7	+	3	3	4	5	8	10
Whiskered Tern			3			1			10		+	4					+	4			1			2	+		+
Number of Sites	0	19	23	0	13	15	7	9	9	9	9	9	2	2	2	3	28	29	0	8	7	3	8	8	20	28	24
Total number of species	1	13	23	0	14	22	15	17	21	24	21	22	6	6	6	13	21	26	0	7	17	6	7	7	31	19	21

Mean total number/ha with 95% limits	2.1	3.1	4.5	5.1	5.2	6.1	6.2	6.5	7.1
M	0	0	11.9 2.9-49	22.6 7-65	0.62	2.9 0-4.8	0	0	9.5 5.3-17
J	4.8 1.6-12	1.5 0.5-3.1	13.9 4.7-40	14.2 4.5-41	0.5	0.9 0.4-1.7	3.8 1.2-9.5	0.65 0-2.5	7.6 4.6-12
O	4.7 2.4-8.7	3.2 1.5-6.1	12.7 1.1-34	21.2 7.3-58	0.74	3.5 2.1-5.6	13.2 3.7-42	1.1 0.02-3.3	11.4 6.7-19

because these wetlands provide habitat similar to shallow and deep permanent open fresh and salt water wetlands and represent only 8% of the area of these categories already present in the study area. The large number of rare species recorded along the western shores of Port Phillip Bay reflect the very prolonged and intensive observations made in the area (Morgan 1954, Watson 1955, Smith 1962 to 1978, Barkla 1978) compared to the few studies in other parts (Binns 1953, Hirth 1976, Missen & Timms 1976), rather than some unique feature of the habitats present.

The detrimental effect of the loss of wetland on waterbird populations is more certain. Sites at which counts were made on freshwater meadows, and shallow and deep water marshes had up to 45, 21 and 117 birds/ha respectively during 1980. The 14 300 ha of these categories which have been lost would have supported substantial populations and similar habitats have not been provided by wetlands created since settlement. Species most affected would presumably be those restricted to freshwater (e.g. Latham's Snipe, Purple Swamphen, Crakes, Dusky Moorhen and Whiskered Tern) and particularly those which rely on such categories for breeding habitat (e.g. Brolga, Australasian Bittern and Black-winged Stilt).

The factors which control the number of species of waterbirds in the area at any one time are complex and depend not only on the condition and area of the wetland categories available but also on rainfall patterns in other parts of Australia which control the movement of many Australian waterfowl (Frith 1967, Cowan 1973, Braithwaite 1975) and day length which regulates the movement of migratory species. Within the area the distribution of the numbers and species present also depends on a number of interacting factors, e.g. the amount and distribution of rainfall, seasonal changes in wetland area, the potential food available and habitat condition of individual basins and the normal range of the species involved. Counts of waterbirds show the effects of these factors and also suggest the important factors acting on the distribution of some species within the area. Species such as Pied Oystercatcher, Black-faced Cormorant, Crested Tern, Fairy Tern, Pacific Gull and many migratory waders occur on marine and estuarine wetlands and do not extend to inland saline areas; Australasian Bittern, crakes and rails occur on deep freshwater marshes with Cane Grass, Lignum or reeds and Banded Stilts are found most often on hypersaline lakes. The distribution of many other species can be linked more precisely to the distribition of potential food particularly as it is influenced by salinity. The upper salinity tolerances of various species of potential food include fish (*Galaxias maculatus*) 30 parts per thousand (ppt) (Chessman & Williams 1974); Gastropoda (*Coxiella*) 100 ppt, Insecta 90 to 120 ppt and Isopoda (*Haloniscus*) 159 ppt (Bayly & Williams 1966); Ostracoda (*Platycypris*) 176 ppt and Anostraca (*Parartemia*) 298 ppt (Geddes 1976) and plants *Ruppia* 60 ppt (Yezdani in Aston 1973) and *Lepilaena* 65 ppt (this study). Thus fish eating species (grebe, cormorant, Pelican) will be confined to salinites of less than 30 ppt; grazing species (Swan and Coot) will not occur at salinities greater than 60 ppt unless they are feeding on grassland above the waterline; species (e.g. Hardhead) feeding on benthic organisms such as *Coxiella* and chironomid larvae will be excluded from waters greater than 100 ppt and the prey of birds (Banded Stilt and Avocet) feeding on highly saline waters must be restricted to only a very few species of microcrustaceans.

The few studies of primary and secondary production (Hammer 1970, Walker 1973, Paterson & Walker 1974, Marchant & Williams 1977) show that production will be highest during summer when incident radiation and water temperature are highest, provided that the water regime and salinity are suitable. Thus Marchant and Williams (1977) showed that the population of *Parartemia* in hypersaline lakes comprises cohorts which originate from hatchings which are most likely to occur following increases in water-level during winter and spring but are unlikely to occur during summer when levels are declining and Pollard (1971b) showed that the population size of *Galaxias maculatus* in Lake Modewarre depends on flood flows in the spawning areas during spring. Production of aquatic plants such as *Ruppia* and *Lepilaena* which comprise the major food of Coot and Swan has not been studied but clearly turbidity and bottom type as well as season and salinity influence their distribution and growth (e.g. Mayer & Low 1970, Congdon & McComb 1979, Verhoeven 1979). It follows that variations in the usage by birds of wetlands of the same category, or of the same wetland from year to year may result from minor seasonal differences in rainfall, turbidity and water chemistry and my observations show that concentrations of birds do occur on particular wetlands presumably when appropriate food is most abundant.

Although there are limited waterbird population data available for other areas of Victoria (e.g. Loyn 1978, Corrick & Norman 1980, Corrick 1981) and regional comparisons are complicated by the annual and seasonal variations which occur in the numbers of many species, counts made during the study indicate that the area supports important numbers of many species. Species for which the area is important include all colonially nesting species (e.g. Straw-necked Ibis, Sacred Ibis, Pied Cormorant, Fairy Tern) but particularly Pelican, the only known recently active colony in Victoria; Gull-billed Tern, the only breeding since 1971-72 (cf. Bourke *et al.* 1973) and Glossy Ibis, the first breeding attempt since 1973 (cf. Cowling & Lowe 1981) and for the non-colonially nesting species Brolga, Australasian Bittern and Chestnut Teal all of which

TABLE 7

NUMBER OF DUCKS BANDED IN VICTORIA AND RECOVERIES BY SHOOTING DURING OPEN SEASONS FROM 1951 TO 1980. The percentage of bandings within the area made at Serendip Wildlife Research Station (38°01'S 144°25'E) is shown.

	Banded			*Recovered*		
	Total	*in area*	*(% at Serendip)*	*Total*	*in area*	*(%)*
Australian Shelduck	3832	3625	(14.2)	982	338	(34)
Pacific Black Duck	7516	5848	(74.4)	2209	517	(23.4)
Grey Teal	67736	60965	(97.7)	13508	4054	(30)
Chestnut Teal	6045	5766	(87.8)	899	281	(31)

have restricted distributions in Victoria. The area is also important for non-breeding populations of many nomadic or migratory species (e.g. Great Crested Grebe, Hoary-headed Grebe, Black Swan, Grey Teal, Pink-eared Duck, Hardhead, Freckled Duck, Blue-billed Duck, Musk Duck, Banded Stilt, Avocet, Coot, Whiskered Tern and several migratory waders in particular Curlew Sandpiper, Red-necked Stint and Sharp-tailed Sandpiper.

Wetlands reserved specifically for conservation in National Parks and Wildlife Reserves include 868 ha of deep freshwater marsh (37% of the area in the region), 1000 ha of permanent open freshwater (6%), 2870 ha of semipermanent saline wetland (36%) including 960 ha or 60% of hypersaline lakes, 4650 ha of shallow and deep permanent saline wetland (13%) and 190 ha of intertidal flats (17%). Only a very small proportion of freshwater meadows (1%) and shallow freshwater marshes (5%) are included in these reserves. In addition large areas (e.g. 11 300 ha of permanent open freshwater, 2700 ha of semipermanent saline wetland and 30 100 ha of permanent saline wetland) of lakes which are on public land are Lake Reserves which recongize their value for recreation, water supply and drainage as well as for conservation. Although their future as wetland is assured, the value of some areas to waterbirds will be lowered unless the requirements of waterbirds are considered. High speed or intensive boating on shallow lakes and increased activity near breeding colonies pose particular threats. At present the large non-breeding populations of waterbirds which use the open lakes and many of the breeding colonies are well protected by reserves; however, some categories (freshwater meadow and shallow freshwater marshes) and the species which utilize them are not. Significant areas of these latter categories should be reserved to ensure that adequate and representative areas of each wetland type and its associated communities are conserved.

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Appendix 1

Wetland Subcategories used by less common, but regularly present Waterbirds. Most common species have been listed in Table 6. Only those subcategories with areas greater than 100 ha are included. x and S, frequently recorded; (x) and (S), infrequently recorded; x and (x), throughout subcategory; S and (S), shores and shallows only; B breeding. Names of categories and subcategories appear in Table 1.

Category	2	3		4			5				6				7	
Subcategory	.1	.1	.4	.5	.6	.1	.2	.3	.1	.2	.3	.5	.1	.2.	3
Australasian Grebe		x	x	x		x		x							
Australian Pelican				x		x	x	x	x				B	x	x
Great Cormorant				x		x	x	x	x				B	x	x
Pied Cormorant						x							B	x	x
Pacific Heron	x	x	(x)	x		S		S					(S)		
Catte Egret	x	x													
Great Egret	x	x	x	x	x	S		S	x				S		x
Little Egret						(S)			x				S		x
Rufous Night Heron				x											
Australasian Bittern					x										
Glossy Ibis	x	x		x									B		
Sacred Ibis	x	x		x	x	S		S					B		x
Royal Spoonbill	x	x	x	x	x	S	S	x	x				S		x
Freckled Duck	(x)						x	x	x				x		
Cape Barren Goose										x	x				
Chestnut Teal						x			x				x		x
Maned Duck								S							
Marsh Harrier			x	x	B	x				x	x				
Australian Crake		x	x	x				S			x				
Brolga	B	B		x	B	S									
Pied Oystercatcher															x
Grey Plover															x
Lesser Golden Plover									x			x	S		x
Red-kneed Dotterel	x	x		x	x	S		S							
Mongolian Plover															x
Double-banded Plover						S			x	x	x		S		x
Red-capped Plover	x	x		x	x	S	S		B	B	x	x	S		x
Black-fronted Plover	x	x		x	x	S	S								
Banded Stilt					x	(S)			x			x	(S)		
Avocet		x		x	x	(S)			x	x		x			(x)
Ruddy Turnstone									(x)						x
Eastern Curlew															x
Grey-tailed Tattler															x
Common Sandpiper															(x)
Greenshank									x				S		x
Marsh Sandpiper									x				S		x
Latham's Snipe	x	x	x		x					x					
Black-tailed Godwit				(x)											x
Bar-tailed Godwit															x
Red Knot						(S)							(S)		x
Great Knot															x
Pacific Gull															x
Gull-billed Tern	x	x	x	x	x	x	x	x	x				B		(x)
Caspian Tern				(x)		(x)							(x)		x
Fairy Tern															x
Crested Tern															x

APPENDIX 2

Vagrant or Rarely Reported Species which Utilize Wetlands of the Area

In some cases (e.g. Black-faced Shag, Hooded Plover) species are more common on other habitats in the area (e.g. rocky shores, ocean beaches or ocean waters). The references cited usually assess specific status or review past records. (* indicates the species was seen during the study).

Darter* (Wheeler, W. R. 1975a, Gilmore *et al.* 1979), Black-faced Shag* (Wheeler, W. R. 1964), Intermediate Egret* (Watson 1955, Abbot & Hughes 1972, Gilmore *et al.* 1979), Little Bittern (Wheeler, J. R. 1959, Gilmore *et al.* 1979), Wandering Whistling-Duck (Wheeler, W. R. 1967), Plumed Whistling-Duck* (Wheeler, W. R. 1967, Gilmore *et al.* 1979), Mallard* (Smith 1969e, Gilmore *et al.* 1979), Garganey Teal (Campbell 1924), Buff-banded Rail, Lewin's Rail* and Spotless Crake (Watson 1955, Wheeler, W. R. 1967, Gilmore *et al.* 1979), Black-tailed Native-hen (Watson 1955, Gilmore *et al.* 1979, LCC 1973), Painted Snipe* (Wheeler, W. R. 1967, Smith 1969a, Gilmore *et al.* 1979), Sooty Oystercatcher (Wheeler, W. R. 1967, Smith 1969a), Hooded Plover *(Wheeler, W. R. 1967), Large Sand Plover (Smith 1964, 1969a), Oriental Plover (Smith 1964, 1969a, Wheeler, W. R. 1967), Whimbrel (Smith 1969a,b), Little Curlew (Smith 1964, 1969a), Wood Sandpiper* (Smith 1964, 1969b) Terek Sandpiper* (Smith 1967, 1969a), Asian Dowitcher (Smith 1974a,b), Pectoral Sandpiper (Smith 1968a,b), Baird's Sandpiper (Smith & Swindley 1975), Long-toed Stint (Smith 1968b, 1969c), White-rumped Sandpiper (Smith 1976, Smith *et al.* 1978), Dunlin (Sympson 1968, Smith 1969d, 1970, 1981), Sanderling* (Wheeler, W. R. 1955, Smith 1969a), Buff-breasted Sandpiper (Smith 1962a, 1977, Wheeler, W. R. 1975b), Broad-billed Sandpiper (Smith 1962b, 1969b, Wheeler, W. R. 1955), Ruff (Carter & Smith 1968, Smith 1969b), Red-necked Phalarope (Smith 1963, Wheeler, J. R. 1976), Wilson's Phalarope (Wheeler, J. R. 1976, Smith 1968a, 1969b), White-winged Tern (Smith 1965, LCC 1973), Common Tern* (LCC 1973) and Little Tern (LCC 1973).